FLORIDA POLYTECHNIC UNIVERSITY

Capstone Design

Design Embodiment

Alexander R. Murphy, Fall 2024

Learning Objectives

For Today

1. Understand the basic principles and importance of parametric design.
2. Learn to identify and define design variables relevant to product performance.
3. Apply analytical methods to optimize design alternatives.
4. Assess design options and refine for improved robustness and cost-efficiency.

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What is Design Embodiment?

“Put Meat on the Bones”

- **Product Architecture:** setting the arrangement of the physical elements of the design into groupings, called modules.
- **Configuration Design:** designing special-purpose parts and the selection of standard components, like pumps or motors.
- **Parametric Design:** determining the exact values, dimensions, or tolerances of the components or component features that are deemed critical-to-quality.

- **NOTE:** Design Embodiment is also called “Preliminary Design” or “System-Level Design”.

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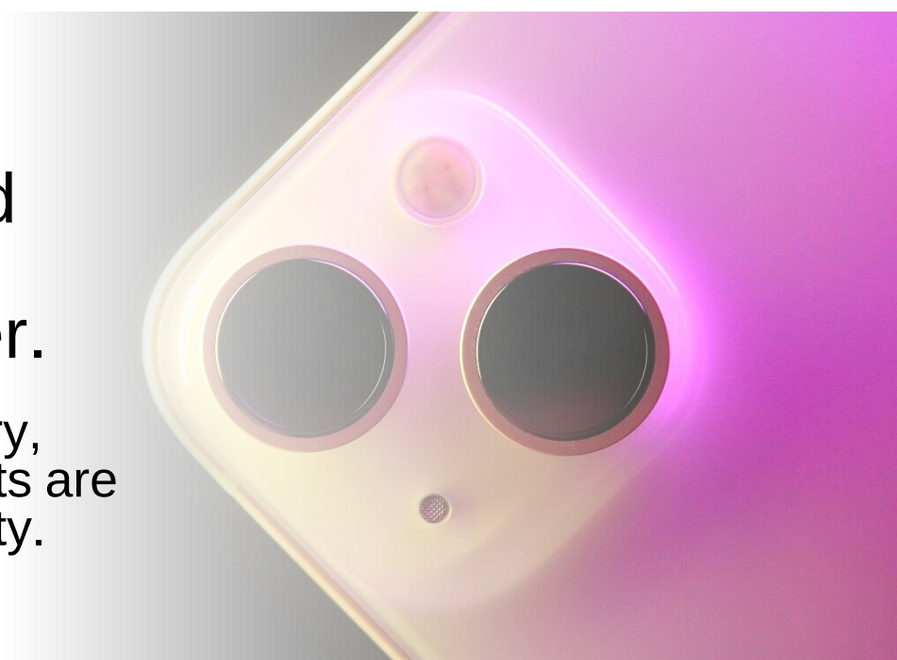
Product Architecture

Modular vs. Integral

- **Modular:** Components or subsystems are independent, interchangeable, and connected via defined interfaces.
  - We can think of the connections between modules as interfaces that transform data or couple physical components.
  - **Example:** A Desktop Computer. Each component (CPU, GPU, RAM, motherboard, hard drive, power supply, etc.) functions as a distinct module with well-defined interfaces (e.g., PCIe slots, USB ports, connectors).

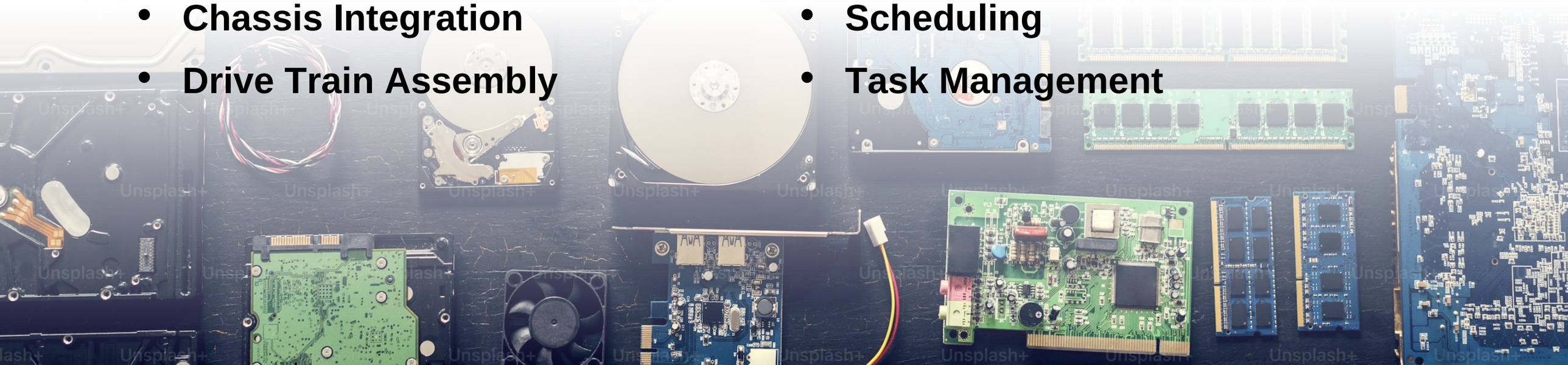
- **Integral:** Components are closely integrated, with multiple functions performed by a single component.
  - In high-performance hardware or specialized software components or functions perform multiple actions and are reliant on each other.
  - **Example:** A Smartphone. Components like the camera, battery, processor, and display are highly integrated. Many components are designed to fit tightly into a small space with minimal modularity.



Product Architecture Cont.

Physical Systems vs. Software Systems

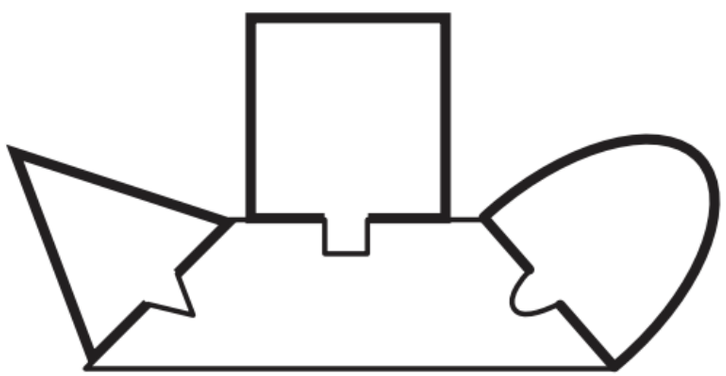
- **Physical Systems:**
  - Bearings
  - Electrical Subsystems
  - Mechanical Subsystems
  - Fan-Motor Sub-Assembly
  - Sensor Networks
  - Fluid Handling Systems
  - Exhaust Systems
  - Chassis Integration
  - Drive Train Assembly
- **Software Systems:**
  - APIs
  - Data Flows
  - Communication Modules
  - UI Components
  - Authentication/Authorization
  - Data Storage
  - Caching
  - Scheduling
  - Task Management



Modular Architecture

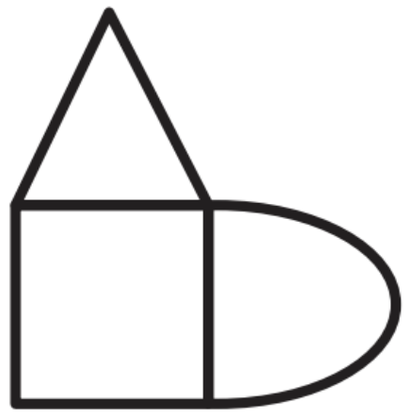
Slot, Bus, & Sectional

- **Slot-modular**: Each of the interfaces between modules is of a different type from the others. This is the most common situation for modular architecture since typically each module requires a different interface to perform its function
- **Bus-modular:** The modules can be assembled along a common interface, or bus. Therefore, interchange of modules can be done readily. The use of a power bus is common in electrical products or shelving systems.
- **Sectional-modular:** All interfaces are of the common type, but there is no single element to which the other chunks attach. The design is built by connecting the chunks to each other through identical interfaces, as in a piping system.



Slot-modular architecture

Bus-modular architecture

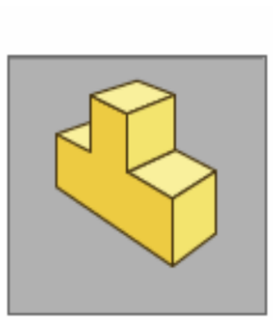


Sectional-modular architecture

Configuration Design

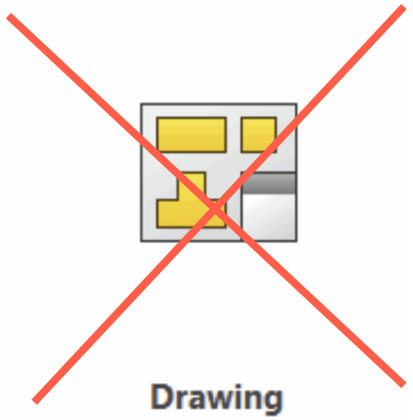
Structuring Components for Function & Form

- **Components** are parts, modules, or systems that perform specific functions, and may refer to parts, assemblies, modules, libraries, or services. This often involves determining shape, dimensions, or software interactions.
- **Part:** A single designed object with no assembly operations. Characterized by geometric features such as holes, slots, ribs, fillets, etc.
- **Assembly:** A collection of parts assembled together.
- **Subassembly:** Assemblies that exist within larger assemblies or systems.



Part

Assembly



Drawing

Not quite to drawings yet…

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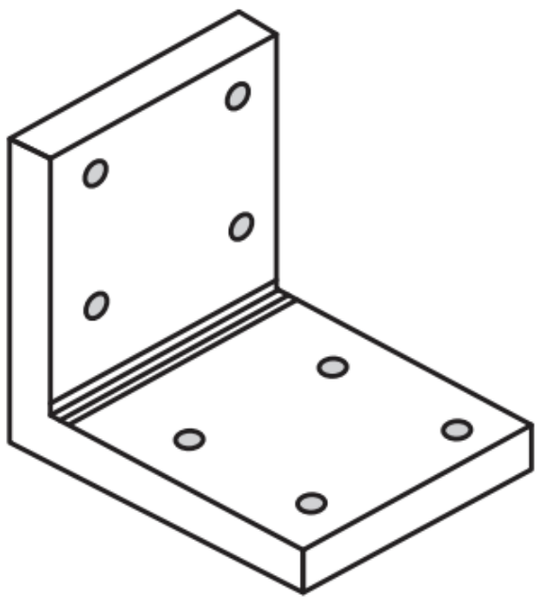
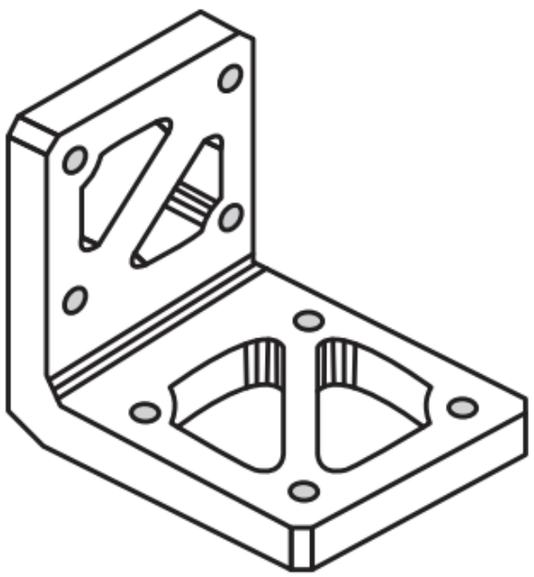
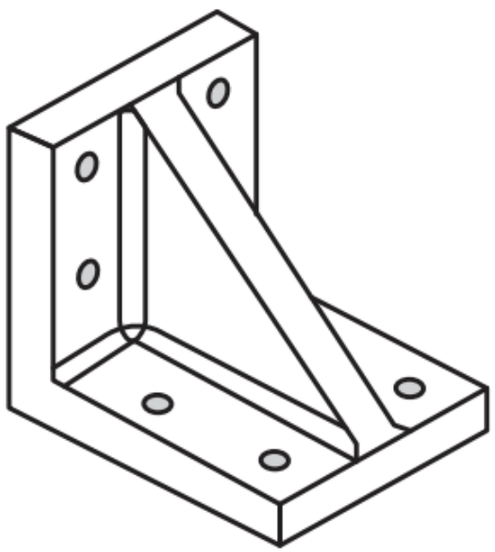
Configuration Design cont.

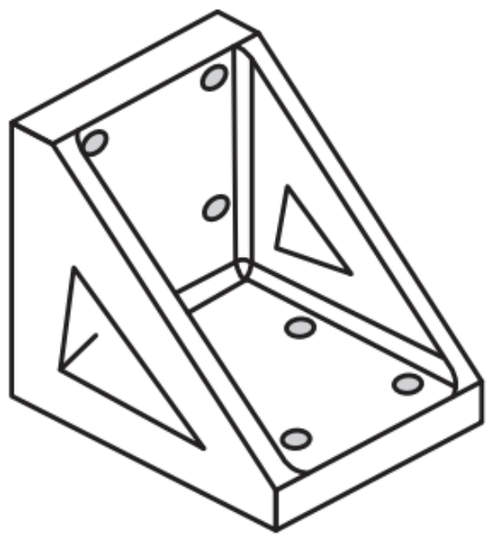
Standard vs. Special

- A **standard part** is one that has a generic function and is manufactured routinely without regard to a particular product. Examples are bolts, washers, rivets, or an API Library.
- A **special-purpose part** is designed and manufactured for a specific purpose in a specific product line such as a unique data analysis algorithm or a custom bracket for aerospace applications.









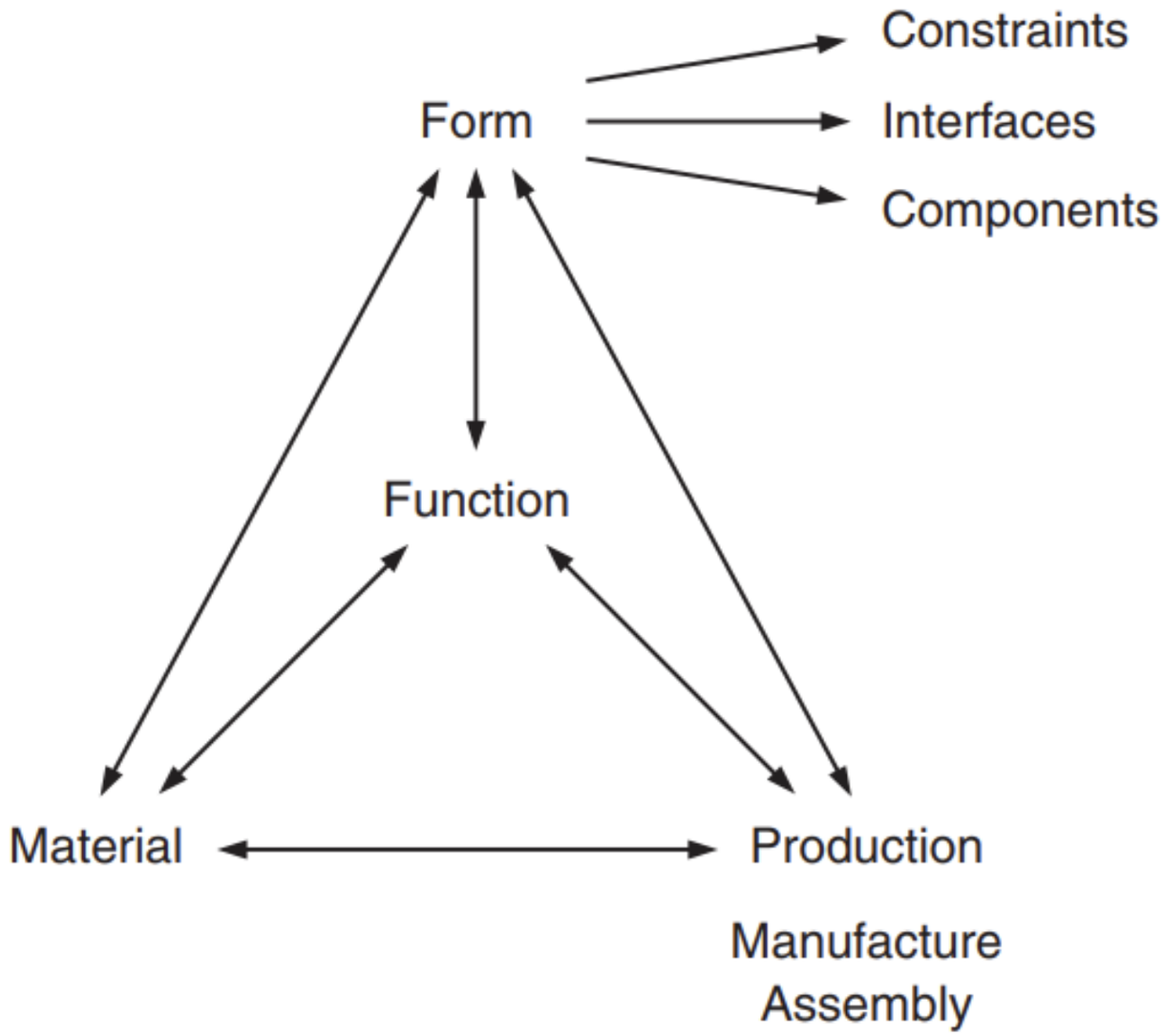
Configuration Design cont.

Form & Function Interrelationships

- **Form depends on function** but is influenced by materials and production methods.

- **Spatial constraints** and **product architecture** impact possible configurations.

- **Material and manufacturing process** decisions are crucial for detailed design choices.



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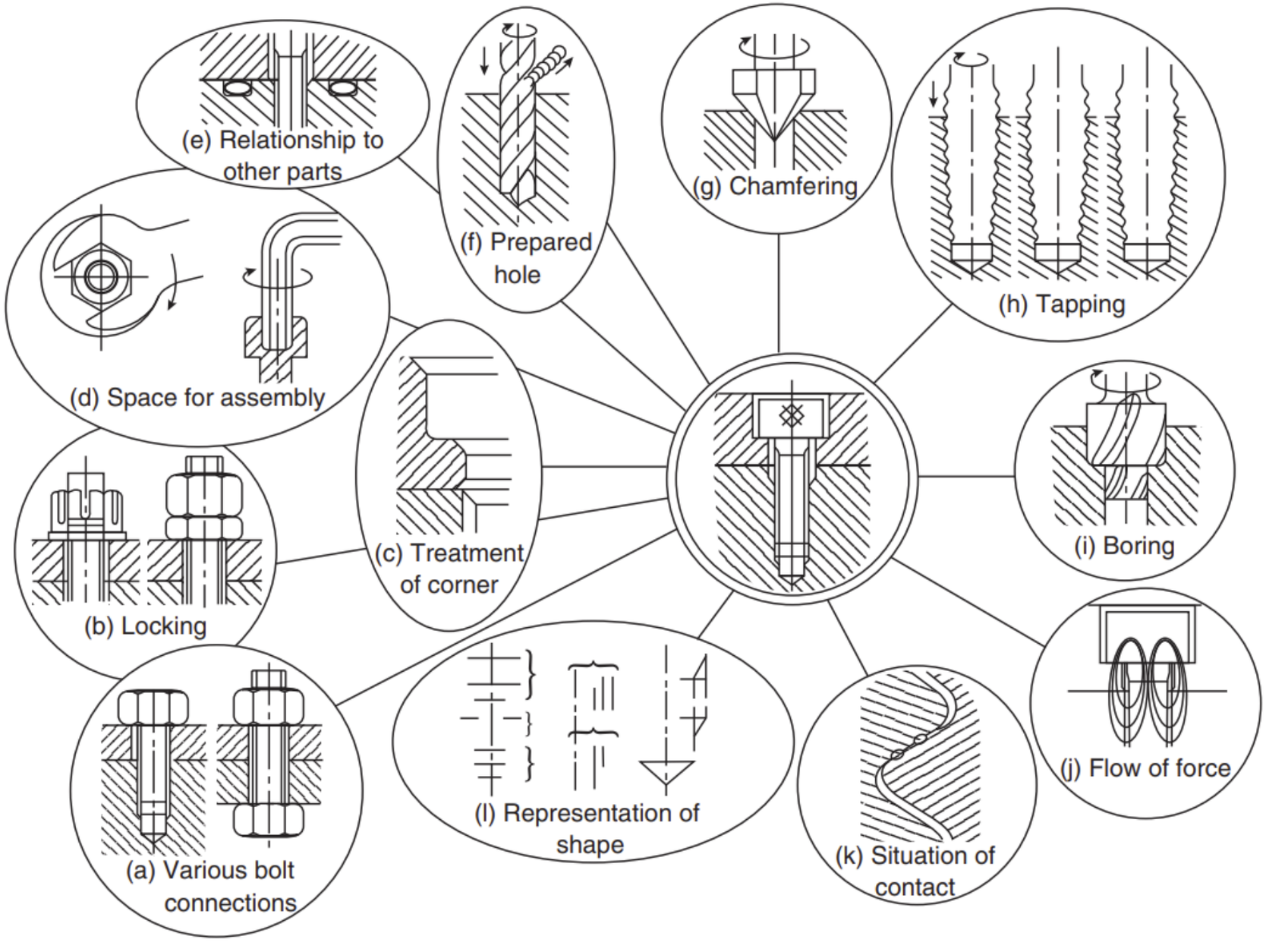
Deciding on a Configuration

What a Designer Imagines

- Images that come to a designer's mind when making a design of a bolted connection:



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Parametric Design

Tuning Design Variables

- **Parametric design** refines attributes identified in configuration design into design variables such as dimensions, tolerances, materials, finishes, algorithms, and data structures.
- This phase is **highly analytical**, optimizing design variables for maximum functionality and cost-effectiveness.
- The primary objective is to set values for design variables that enhance performance while considering manufacturability or code stability to **minimize costs**.
- **Emphasize** creating robust products or systems that perform reliably under a wide range of service conditions, not just ideal scenarios.

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Parametric Design

The Design Process Again, but Focused

- **Step 1:** Formulate Parametric Design Problem
  - Define the component's function based on the Product Design Specification and establish key performance metrics and design variables.
- **Step 2:** Generate Alternative Designs
  - Create various candidate designs by experimenting with different values for the design variables.
- **Step 3:** Analyze Design Alternatives
  - Evaluate each design's performance using analytical or experimental methods to determine feasibility.
- **Step 4:** Evaluate Analysis Results
  - Compare all feasible designs using performance metrics to identify an optimal solution.
- **Step 5:** Refine/Optimize
  - Adjust and optimize design variables to enhance the chosen solution, applying design optimization techniques as necessary.

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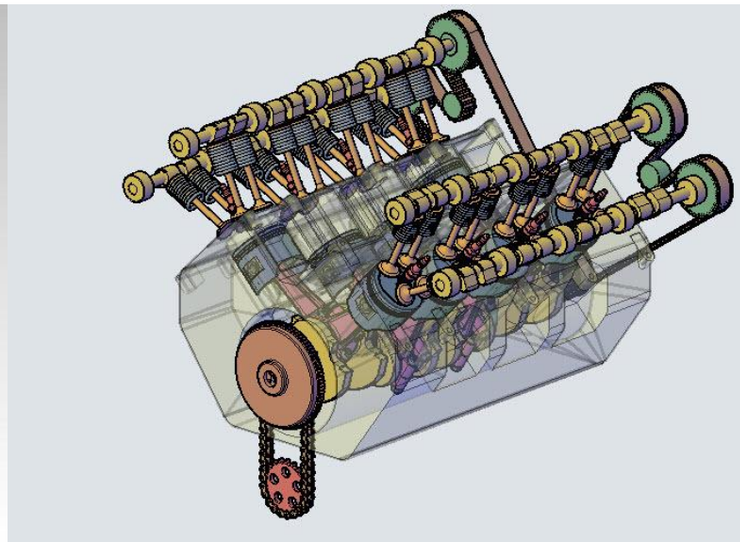
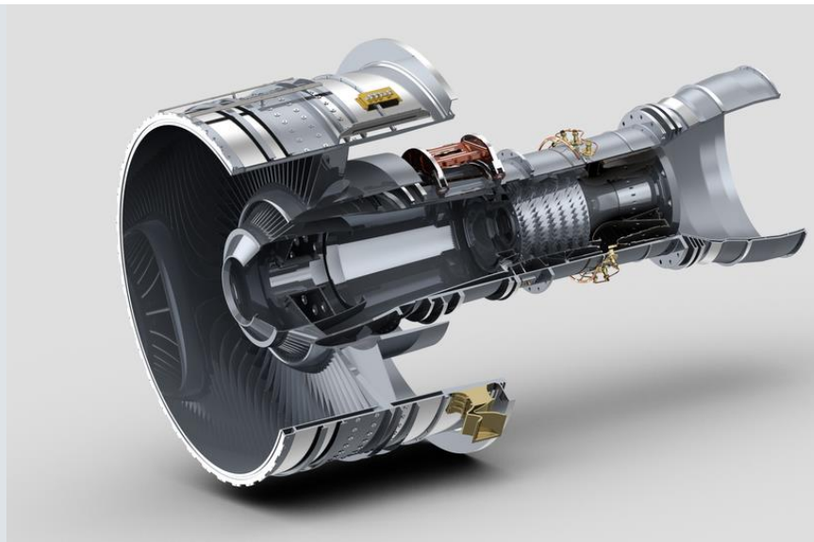
Computer-Aided Design

or just “CAD”

CAD is a technology used to create, modify, analyze, and optimize designs in a digital environment.

- **2D and 3D Modeling:** Allows designers to create detailed two-dimensional drawings and three-dimensional models.
- **Simulation Capabilities:** Enables simulation of how a product will behave in the real world, reducing the need for physical prototypes.
- **Automated Tools:** Includes tools for drafting, dimensioning, and other design-related tasks, which automate repetitive tasks and improve accuracy.





CAD Resources

Software Options

- **Solidworks:** 3D design and simulation, widely used in engineering
- **Onshape:** Multi-user server-based 3D design and simulation
- **Fusion 360:** An integrated CAD, CAM, and CAE software
- **ANSYS:** A comprehensive engineering simulation software
- **Blender:** An open-source 3D modeling, animation, and rendering software
- **Maya:** A powerful software for 3D animation, modeling, simulation.
- **GitHub:** A web-based platform used for version control and collaboration.
- **Visual Studio Code (VS Code):** A lightweight but powerful source code editor from Microsoft

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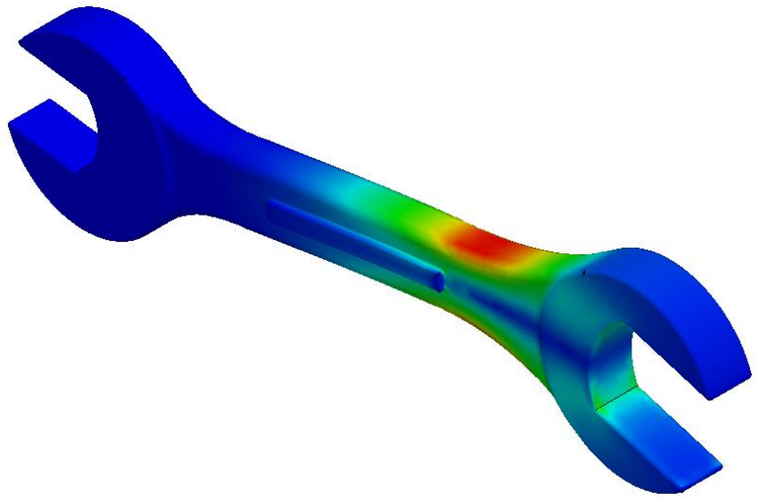
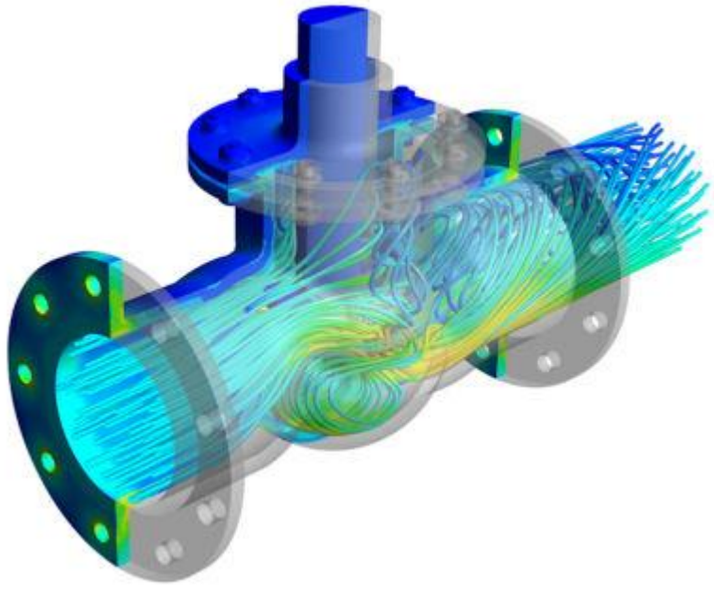
Simulations

Virtually Testing your designs



- Virtual environments
  - Intended to allow for mock deployment of software
  - Allows for testing configurations, parameters, and tolerances
- System scale models
  - Simulink (useful for modeling signals and controls)
  - Arena (modeling factory environments)
- Finite Element Analysis
  - Numerical modeling for complex problems
  - Solidworks, ANSYS, Onshape can do this



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UI / Web / App Mockups

Charcutier vs. Smoothie

- Use easily recognizable conventions
  - Account for cultural differences / nuances
- Create effective visual hierarchies
  - Important things should appear prominent
  - Logically related things should be visually grouped
  - Use nesting when necessary to show hierarchy

- Clearly define separate pages/views
- Make it obvious what users can interact with
- Less is more
- Format text to support scanning

Krug, Steve. *Don't make me think!: a common sense approach to Web usability*. Pearson Education India, 2000.

The headline spanning these four columns makes it obvious that they're all part of the same story.

The size of this headline makes it clear at a glance that this is the most important story.

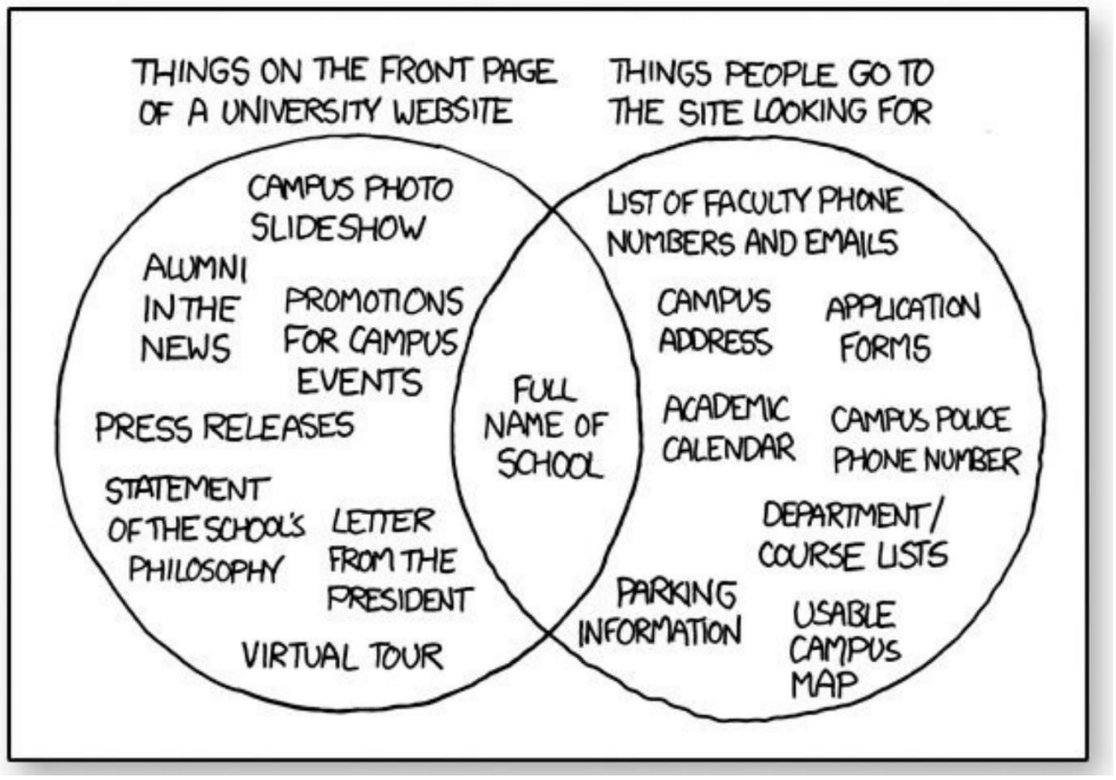
University Websites

Where is the Parking Page?

ACTIVITY

1. Select 1 or 2 things you might want to know about a university.
2. Choose a university website other than Florida Poly's website.
3. See how long it takes you to find the page you are looking for by navigating from the homepage.
4. How would you improve the UI to make navigation easier to find?

https://floridapoly.edu/



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References

Questions?

- Lewrick, Michael, Patrick Link, and Larry Leifer. *The design thinking playbook: Mindful digital transformation of teams, products, services, businesses and ecosystems*. John Wiley & Sons, 2018.
- Lewrick, Michael, Patrick Link, and Larry Leifer. *The design thinking toolbox: A guide to mastering the most popular and valuable innovation methods*. John Wiley & Sons, 2020.
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